Wyman-Gordon Company

Incremental Forging Process for Gas Turbine Applications

In the early 1990s, U.S. producers of large superalloy forgings (or disks) for the power-generation industry competed in a price-driven commodities market dominated by two foreign suppliers. At the time, these two suppliers jointly owned and used the largest commercial forging press. In order to compete with these foreign companies, Wyman-Gordon Company, one of the United States' largest metal forgers, proposed an innovative forging process and tooling design. The company sought to use its smaller press to manufacture extremely large, cost-effective, near-net-shape forgings for advanced gas turbine applications, specifically land-based gas turbines (LBGTs). They would use two nickel-based superalloys: alloy 706, which was used in current engines, and alloy 718, to be used in future engines. Building a larger forging press was not an alternative due to the exorbitant cost. Therefore, Wyman-Gordon proposed an incremental forging process that had not yet been applied to LBGTs in which only a portion of the workpiece is forged during each forging stroke.

In 1995, the company was awarded cost-shared funding for an 18-month project from the Advanced Technology Program's (ATP) focused program competition in "Materials Processing for Heavy Manufacturing." Upon completion of the ATP project, Wyman-Gordon had successfully developed an incremental forging process using alloy 706 that achieved a 20-percent reduction in necessary materials and in overall cost. In contrast, the company was unable to commercialize LBGT forgings made with alloy 718 due to technical difficulties.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 95-07-0026 were collected during fall 2001.

Foreign Competition Limits Domestic Forgers' Market Share

Forging, a process for shaping metal parts, is used to produce large quantities of identical parts, such as disks for land-based gas turbine (LBGT) engines. In 1995, U.S. producers of large superalloy forgings (disks made with alloys possessing superior mechanical properties at high temperatures) for the power-generation industry were losing market share to foreign competitors, primarily to two French companies, Aubert & Duval and Fortech. Both companies were using the same French 72,000-tonnage press. Their press had a 44-percent higher tonnage capability than the two largest presses in the United States at 50,000 tons, which were owned by Wyman-Gordon and Alcoa. The two largest presses in the world, not commercially available at the time, were in Russia; each was an 82,000-tonnage press.

France's superior forging press limited the United States' ability to compete in the global market. In fact, in 1995, annual U.S. imports of superalloy forgings totaled $50 million. This amount, which represented a significant loss of potential sales for domestic suppliers, was expected to increase unless a dramatic change in domestic production was made.

The market for LBGTs (i.e., non-aviation gas turbines) was approximately $75 million in 1995. Although Wyman-Gordon's annual sales in this market were $5 million, the company believed it could develop a new technology that would increase its annual revenue stream to $50 million within four years. This increased market share would be won at the expense of foreign suppliers of forgings. At the time, General Electric (GE) was one of the largest developers of LBGTs and was importing vast amounts of forgings from France. However, GE was seeking a domestic partner that could provide it with forgings similar to those supplied from France. The domestic products needed to be equal to or superior in quality and be competitive in price. GE expressed interest in developing a relationship with Wyman-Gordon to supply the desired forgings. With GE's technical support, Wyman-Gordon proceeded to investigate developing a new forging technology.

Novel Incremental Forging Process Uses Smaller Press

In the early 1990s, Wyman-Gordon determined that the most cost-effective way to compete in the market was to design a process using smaller tonnage presses that could replicate the force and power of a larger tonnage press. The company planned to accomplish this by adding a rotating tooling mechanism to its existing press and by using an innovative tooling approach that would involve incremental forging, in which only a portion of the workpiece is forged during each forging stroke. This new approach would limit the amount of tonnage required to achieve a given level of deformation, enabling Wyman-Gordon's 50,000-tonnage forging press to function as a significantly larger press, comparable to the French 72,000-tonnage press. The smaller press would be able to shape forgings to a more near-net shape (i.e., close to the final shape), reducing the amount of raw material required and limiting the machining needed to achieve the geometry of a part.

U.S. producers of large superalloy forgings power-generation industry were losing market share to foreign competitors.

Wyman-Gordon had the expertise to develop such a process on its own, but its limited funds would have prolonged the development cycle. Moreover, the alternative to the new process, building a press that was larger than its competitors', was cost prohibitive. A large press was estimated to cost $1 million per thousand tons; therefore, a 100,000-tonnage press would cost about $100 million. Furthermore, it was crucial that Wyman-Gordon introduce its new approach within two years because international competition was threatening U.S. market share.

Wyman-Gordon Pursues External Funding Assistance

Wyman-Gordon understood that additional funding was essential to the timely development of the incremental forging process; thus, it initiated a search for funding assistance. In 1995, the company applied to ATP's focused program competition in "Materials Processing for Heavy Manufacturing." This program was set up to promote economic growth by supporting sustained, high-risk research and development to accelerate the introduction of advanced materials technologies into heavy manufacturing.

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Emphasis was placed on the introduction of both 1) advanced materials technologies into machinery and equipment products and 2) advanced machinery and equipment into the production and processing of the materials for these products. Wyman-Gordon believed its technology would meet these criteria, and the benefits resulting from this technology would impact many domestic original equipment manufacturers, as well as Wyman-Gordon. ATP awarded Wyman-Gordon $1 million in funding assistance for an 18-month project.

Process to Reduce Raw Materials Consumption

There were three technical goals for this ATP-funded project:

- Design an incremental forging process.
- Engineer the mechanisms and tooling necessary to execute the process.
- Apply the process to the production of LBGT forgings of the nickel-based superalloy used in current engines (alloy 706), as well as the superalloy to be used in future engines (alloy 718), which would have a higher temperature capability.

Key parameters for investigation during this project included studying thermomechanical processing and near-net-shape geometry. At the time, there was limited knowledge of how incremental forging and heat treatment would affect the microstructures and mechanical properties of superalloy disks. In addition, Wyman-Gordon sought to develop a process that would maximize near-net-shape geometry. Increasing near-net-shape geometry in the forging is the most effective way to reduce the required amount of raw materials, which is the largest cost component.

Improved Computer Process Modeling Enables Development

Three-dimensional (3-D) computer process modeling of the incremental forging, which eliminated costly trial and error, was instrumental in the successful development of the forging process and of a new forging press top die (a forging tool for imparting a desired shape or form). Previous forging press designs had utilized 2-D process modeling for more than 10 years, but now, with faster and more affordable computers and software, 3-D process modeling was a valuable production tool.

Desired Results Are Achieved

Originally, Wyman-Gordon proposed and was awarded funding for an 18-month project; however, due to complications at its Houston facility and the company's ambitious expectations, the project was extended at no cost to ATP for an additional 18 months. Upon completion of the project in 1998, Wyman-Gordon had achieved its proposed goals. The company had developed and demonstrated the feasibility of a novel forging process that would enable existing presses to form near-net-shape parts. It had taken Wyman-Gordon many steps to achieve the milestones needed to achieve the desired results with this incremental forging process.

First, during the ATP-funded project, 3-D computer process modeling was used to evaluate potential designs for the incremental forging process, as well as several additional process variables. The 3-D modeling was instrumental in reducing the time and cost associated with the project. Second, microstructure and mechanical property analysis was used to examine the effects that the incremental forging process would have on the superalloy forgings. This subscale work enhanced Wyman-Gordon's understanding of the metallurgical behavior of the two superalloys, and this knowledge is now also being used to improve forgings for other markets, such as aerospace. Third, the company designed and constructed the incremental tooling mechanism. This mechanism consistently transmits 50,000 tons of force to the forging and also allows rapid rotation and repositioning of the forging dies between each forging stroke. Fourth, Wyman-Gordon conducted a successful full-scale trial of incremental forging on stainless steel. This led to the fifth milestone of fabricating and evaluating an alloy 706 forging. The results from this forging were quite favorable. In fact, the microstructures and mechanical properties measured in the forging were equivalent to those achieved during conventional forging using much larger presses.

Wyman-Gordon understood that additional funding was essential to the timely development of the incremental forging process.

The final milestone was the fabrication of an alloy 718 forging using the incremental forging process. The company experienced some difficulty in achieving desired mechanical properties at certain temperatures for the alloy 718 forging, which was to be used in future engines operating at higher temperatures. However, when the temperature was lowered, this forging also achieved favorable results. With positive results for both alloy 706 and 718 forgings, Wyman-Gordon was poised to initiate its new method of forging for LBGT engines.

Incremental Forging Increases Wyman-Gordon's Market Share

The incremental forging process developed as a result of this project has allowed Wyman-Gordon to compete for new business. In 1995, at the start of the ATP-funded project, Wyman-Gordon held approximately 13 percent of the $50 million market for alloy 706 forgings for LBGT applications. The reduction in input of raw materials resulting from the incremental forging process made Wyman-Gordon competitive. In addition, through the use of its new technology, Wyman-Gordon has achieved a 20-percent price reduction in LBGT forgings.

Market and Outlook for LBGT Engines Change

At the outset of this project in 1995, the market for LBGT engines was expected to grow substantially, with the majority of the growth anticipated in Asia. However, as the economy in Asia slowed, so did the demand for LBGT engines and forgings for these engines. Accordingly, Wyman-Gordon shifted its focus to domestic markets. The company expected its short-term growth in sales to result from GE's power-generation engines, which are designed to serve many markets including the aircraft industry.

Wyman-Gordon conducted a successful full-scale trial of incremental forging on stainless steel.

Wyman-Gordon is continuing to advance its successful incremental forging technology. Since the completion of the ATP-funded project, the company has improved the die materials involved in the process. Although the demand for its alloy 706 forgings has continued to increase, commercialization of alloy 718 forgings has not occurred. Wyman-Gordon encountered technical difficulties associated with alloy 718 that have prevented its commercialization.

Conclusion

In 1995, with funding assistance from ATP, Wyman-Gordon developed an incremental forging process to produce forgings for advanced gas turbine applications, specifically land-based gas turbines (LBGTs). These forgings were made with two nickel-based superalloys: alloy 706 for current engines and alloy 718 for future engines. As a result of this ATP-funded project, Wyman-Gordon can use its 50,000-tonnage press to produce large near-net-shape, nickel-based superalloy components made with alloy 706. Previously, these components could only be produced using presses with much higher tonnage capabilities, such as the 72,000-tonnage press in France.

Wyman-Gordon has increased its market share, which has enabled an increase in domestic market share across the forging value chain. In addition, Wyman-Gordon has reduced its forging costs and input materials by 20 percent. Due to current global market conditions, however, the market is flat and is expected to remain so until economic conditions improve. Despite its success with using alloy 706, the company experienced technical difficulties using alloy 718 and, thus, was unable to commercialize LBGT forgings made with this superalloy.

PROJECT HIGHLIGHTS
Wyman-Gordon Company

Project Title: Incremental Forging Process for Gas Turbine Applications (Cost-Effective Near-Net Shape Superalloy Forgings for Power-Generation Gas Turbines)

Project: To design and develop an innovative forging process and tooling technology that enables U.S. metal forgers to achieve cost-effective production of larger, near-net-shape nickel-based superalloy forgings for advanced gas turbine applications using existing presses.

Duration: 9/1/1995-5/31/1998
ATP Number: 95-07-0026

Funding (in thousands):

ATP Final Cost	$687	65%
Participant Final Cost	375	35%
Total	$1,062	

Accomplishments: Wyman-Gordon successfully developed an incremental forging process to produce near-net-shape forgings for industrial gas turbines using a lower tonnage press than was previously possible. Moreover, the company reduced input billet weight by 20 percent for alloy 706 forgings. The company also decreased forging costs by 20 percent.

Commercialization Status: Wyman-Gordon has incorporated the incremental forging process into its business operations.

Outlook: Wyman-Gordon believes that the incremental forging process is key to increasing its market share in the large industrial gas turbine forgings market. The company has not identified a new market for the incremental forging process. It believes that the process in its current state is only suitable for large industrial gas turbine applications.

Composite Performance Score: *

Focused Program: Materials Processing for Heavy Manufacturing, 1995

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